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A REVIEW OF THE LITERATURE ON SPRAYS TO DESTROY OVERWINTERING CODLING MOTH LARVAE

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Treatments applied against the hibernating worms (Thacher 35) were among the earliest measures suggested for control of the codling moth (Carpocapsa pomonella (L.)):

"All the rough bark should be carefully removed, and the trunk and large branches should be thoroughly washed with Forsyth's composition or a strong decoction of tobacco with the addition of a small quantity of quick lime, which should be applied to every crevice which can afford shelter for insects or their eggs."

The wash suggested contained urine, soap suds, fresh cow dung, and lime, in indefinite proportions.

Similar suggestions may have been made subsequently, from time to time, but the older literature has not been systematically reviewed, since the control of the codling moth in the hibernating stage does not appear to have been developed to a practical point until the present decade.

The earliest reference we find in recent literature to this method of control is Jegen's (23) recommendation in Switzerland, that apple trees be scraped, the debris burned, and the trees then sprayed with a 5-percent solution of soft soap. Lehman (24), in Germany, advised cleaning the dead bark, moss, and so forth, from the trees in winter, and then painting them with a fairly thick lime wash containing 10 percent of fruit-tree carbolineum. Maag (25), in Switzerland, stated that the two winter sprays of real value to the fruit grower were lime-sulfur and fruit-tree carbolineum of a reliable brand, which was very effective against Carpocapsa pomonella. Other materials, he said, were quite as effective, but more expensive.1/

Hough (22), in the United States, stated that oil sprays applied in the dormant season were not effective in killing the worms in their winter cocoons. Worms in their winter cocoons had been seen to survive

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1/ Several references, especially from England and Germany, refer to carbolineum and dinitro-o-cresol winter sprays, but these materials appear to have been used against insects other than the codling moth.

100 percent a submergence of 15 hours in an oil spray (Medina oil) diluted for winter spraying. Chandler (9), reporting on work done in the winter of 1926-27, stated that boiled fish-oil soap emulsion up to 25 percent of soap failed to kill cocooned overwintering larvae in laboratory tests. McAlister (26), reporting on laboratory tests made in 1927-28 with 12 formulas, found that undiluted kerosene and undiluted tetrachloroethane killed 100 percent of the hibernating larvae cocooned between pieces of bark, and that a 5-percent solution of tetrachloroethane killed 94 percent.

McAlister's work was followed by that of Headlee (17, 18, 19, and 20), in which he made tests on codling moth larvae cocooned on apple trees, using Pineol - Soluble, one of the fractions obtained by distillation of pine stumps, roots, and branches, treated with caustic soda to make it miscible with water. When applied to apple tree trunks 10 inches in diameter, late in March and early in April, at full strength, or diluted with equal parts of water, it killed 100 percent of the larvae.

Cory and Sanders (12), in laboratory tests of 26 materials against larvae cocooned in rolls of corrugated-paper bands dipped in the formulations, found Pineol - Soluble plus paradichlorobenzene 1 to 7.5 and 1 to 2 and undiluted Pineol - Soluble the most effective, killing 87.5, 93.6, and 99.6 percent, respectively. Paradichlorobenzene added to several brands of oil emulsions and soluble oils did not increase their effectiveness, but when added to tar washes and pure oils it apparently increased their kill.

Thompson and Worthley (36), in blocks of orchard trees treated with a blend of various fractions of steam-distilled pine oils called Hybrex, which was applied with a brush to the bark of the trees, obtained a kill of 95.8 percent, with a reduction of 33 to 67 percent of the first-brood injuries.

Ginsburg (14), in tests of fumigants against overwintering larvae, found them most susceptible to ethylene chlorohydrin and hydrocyanic acid and the least to carbon bisulfide and ethyl acetate.

Paillot (31), in France, reported that tar-distillate sprays, applied just after the buds split in the spring, failed to give satisfactory control of hibernating codling moth larvae. Spyer (34) reported that in Germany codling moth larvae, even when removed from their cocoons, were very resistant to high concentrations of tar distillates.

Marshall (27) reviewed preliminary unpublished work done by Steiner of Indiana, in which 24 materials were tested. He described tests of treatments of cavities containing cocooned larvae, with paraffin, lime, and alpha-naphthylamine. Miller (29) stated that codling moth larvae could be controlled with a dormant spray, and that such a spray was being patented (by him).2/

2/ Patent lists do not show grant of such a patent.

Brandt (2) reported extensive practical use of steam for destroying overwintering codling moth larvae on the trunks and crotches of apple and pear trees in California.

In orchard experiments conducted by Gnadinger et al. (16), it was found that a pyrethrum-oil spray killed 100 percent of the overwintering larvae on the trees after harvest. These investigators proposed destroying the larvae in the upper two-thirds of the trees by treating them with pyrethrum-oil applied by means of a hand-operated oiler, and in the lower third by applying this material as a spray. United States patent No. 2,267,150 was granted December 23, 1941, covering this method of control of the overwintering larvae.

Ginsburg (15) concluded that dichloroethyl ether was highly toxic to the larvae at concentrations of 0.75 percent or higher under laboratory conditions, but that it failed to kill a sufficiently high percentage of the larvae in the orchard because of lack of penetration. Kerosene at 17 percent or higher killed from 93 to 100 percent both in the laboratory and in the orchard. Injury to the trees occurred only when the kerosene was applied in the summer---not when it was applied in the spring.

Carlson and Yothers (4) described and figured a mechanical timing device which they developed and used in their laboratory tests of sprays to kill codling moth larvae cocooned in grooved pupation sticks.

Heriot (21), in an orchard experiment involving 5.5 acres of unsprayed trees, showed that a single dormant application of an oil solution of dinitro-o-cresol to trunks and main limbs was highly effective in reducing codling moth infestation at harvest. The oil carrier injured the trees, however. Heriot also found that dinitro-o-cresol oil residue persisted for at least 210 days to such an extent as to kill full-grown larvae entering corrugated paper bands treated with it.

Yothers et al.(42), in an orchard test with 23 formulations, obtained a high kill of hibernating larvae on apple trees with nicotine sulfate, pyrethrum extract, dichloroethyl ether, and 4,6-dinitro-o-cresol. Each of these materials was prepared in an emulsion with stove oil and a penetrating material. Owing to the scarcity of all these toxicants except the dinitro compound during the war, work was concentrated upon it. Used at 3 or 4 pounds per 100 gallons emulsified in 10 or 15 gallons of stove oil (32 sec. Saybolt at 100° F.) with suitable emulsifiers and penetrants, it gave kills of 91 to 100 percent in a number of orchard tests (Yothers et al. 43). This spray was found to be toxic to apple buds even in the dormant stage, and it was therefore recommended only as a dormant spray to be used on the trunks and lower scaffold branches.

Alexander (1) tested a pyrethrum-kerosene solution applied on the rough bark of the trunks and lower branches of apple trees while the trees were still dormant. The dropped and picked fruit from untreated trees for the season had more than four times as many worm-injured apples as did trees that had no other codling moth sprays. The spray caused no

apparent injury, and showed no repellent action to the larvae. It was suggested that the use of this spray should obviate the necessity for much of the scraping of loose bark from the trees, and that it should be effective against the larvae hibernating in prop poles.

Newcomer et al. (30) gave a brief discussion of the work with trunk sprays to destroy overwintering larvae which was in progress at the laboratory of the Bureau of Entomology and Plant Quarantine at Yakima, Wash.

Robertson (32), reporting on work by Venables and Heriot of British Columbia, stated that sprays containing kerosene, diesel oil, and dinitro-o-cresol were successful in destroying overwintering codling moth larvae on the trunks and rough bark of apple trees. The oils injured the trees temporarily but they recovered the following season.

Carlson et al. (3) found that codling moth cocoons, spun without extraneous materials--wood, bark, and so forth--contained about 25 percent of wax and fat, while those containing extraneous materials averaged about 12.5 percent of these substances.

In 1944 Carlson and Yothers (5) gave directions for the preparation and use of the dinitro-o-cresol concentrated tree-trunk sprays. The authors stated that at least one manufacturer was preparing a commercial product based upon their formula.

Yothers and Carlson (38, 39) reported results of 3 years of orchard tests with dinitro-o-cresol on 2 to 4 acres each year. In the six tests kills of 84 to 95 percent were obtained, and in small-scale tests (3 to 5 trees each) kills of 85 to 99 percent. They reported that several hundred acres of apple and pear orchards in the Yakima Valley and elsewhere had been sprayed with the dinitro-o-cresol tree-trunk spray.

Carlson and Yothers (6) corroborated the findings of Heriot (21) that the residue of the dinitro spray is highly persistent on apple trees, killing considerable numbers of larvae as long as 14 months after it had been applied.

In the Report of the Chief of the Bureau of Entomology and Plant Quarantine for 1944 (37), reference is made to experiments against the codling moth on apples in Washington as follows: "Field tests with a dinitro-o-cresol spray to destroy hibernating codling moth larvae... killed 86 to 94 percent of the larvae and reduced the subsequent infestation in fruit 25 to 50 percent." Chandler (10), in tests of dinitro-o-cresol and either fuel oil and fish-oil soap or Dendrol (a miscible oil for dormant sprays), obtained a maximum kill of 71 percent of hibernating larvae. Gardner (13), in his report on work of Venables and Heriot in British Columbia, stated that a light petroleum emulsion of dinitro-o-cresol or dinitro-o-cyclohexylphenol applied to trees in early spring killed up to 80 percent of the hibernating larvae and reduced the infestation at harvest by 50 percent. The treatment was recommended to supplement summer sprays. Robertson (33), also summarizing Venable's and

Heriot's work in British Columbia, stated that 80 to 86 percent of overwintering larvae were destroyed by spraying with a mixture of 15 gallons of diesel oil and 3 pounds of dinitro-o-cresol per 100 gallons.

Yothers and Carlson (40), in laboratory experiments, found that codling moths developing from larvae that had survived sublethal concentrations of 4,6-dinitro-o-cresol sprays deposited fewer eggs than did moths developing from untreated larvae, and also that the eggs deposited by these surviving moths were less viable than are normal eggs.

Carlson and Yothers (7) reported on preliminary tests for destroying full-grown codling moth larvae with trunk sprays on apple trees in the summer. The regular (penetrant) formula of dinitro-o-cresol killed 82 percent, and DDT killed 85 percent of the naked larvae placed on recently sprayed trees, 68 and 28 percent, respectively, after 31 days, and 79 and 20 percent 61 days after treatment.

Carlson and Yothers (8) reported the use of a penetrant aid, Celite 209 (a finely divided diatomaceous earth), which apparently served as a deposit to faciliate penetration of the dinitro spray through the waxy cocoons.

Marshall (28) reported that DDT-oil in a trunk spray was considerable less effective than dinitro-o-cresol-oil against mature hibernating codling moth larvae.

Chandler (11) reported a test on 30 acres in 1946 using dinitro-o-cresol and a proprietary oil emulsion. The final percentage of wormy fruit was 0.5 in the "eradicant"-sprayed plot and 2.6 in the check. The heavy spray schedule in both plots "might have controlled the insects regardless of dormant sprays."

In 1947 Yothers and Carlson (41) prepared instructions for the preparation and use of their tree-trunk spray. The authors stated that in several seasons' tests in large-scale orchard plots this spray gave 80 to 95 percent kill of all overwintering worms on the sprayed parts of the trees. However, even when the trunk spray is applied, regular summer sprays will be necessary, but the continued use of trunk sprays should reduce the number of summer sprays.

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